Comparison of Forwarding Strategies in Internet Connected MANETs

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Why is it complicated to integrate MANETs with the Internet?

Mobile ad hoc networks (MANETs) are often envisaged to have flat addressing (no prefixes) and flat routing. Nodes are also mobile and there may be multiple gateways. This makes it challenging to integrate ad hoc networks with the Internet. One overlooked issue for Internet connectivity is forwarding to gateways. Our contribution is to compare the ability of forwarding strategies to efficiently support:

- Multiple gateways – Mobile IP requires gateway changes to be tracked
- Hand-over – maintaining two gateway connections at once
- Multi-homing – route over multiple gateways

We look at two common strategies; default route forwarding and tunnel forwarding in networks with reactive routing.

Forwarding using Default routes

Default routes are commonly used in LANs where nodes share a subnet and there is one hop to the gateway. In MANETs, however, flat addressing, multiple gateways and reactive multi-hop routing eliminates many of these premises. Because there is no subnet, we need to add host entries for routing (route table (a)). A gateway entry is needed to track gateways (route table (b)).

Destination	Next Hop	Hop Cnt
63.3.5.23	63.3.5.23	1
66.35.250.151	default	–
default	63.3.5.23	3

(a)

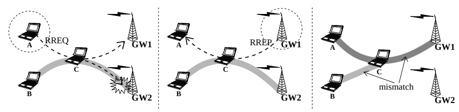
Destination	Next Hop	Hop Cnt
192.168.1.1	63.3.5.23	3
63.3.5.23	63.3.5.23	1
66.35.250.151	default	–
default	192.168.1.1	3

(b)

Two problems with default route forwarding in multi-hop ad hoc networks:

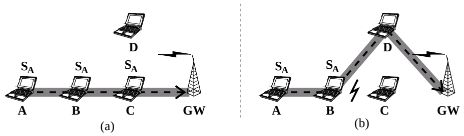
Gateway Tracking:

A default route can be repointed to another gateway on downstream nodes (see figure below). This will break connections when using a gateway running NAT or Mobile IP (MIP). In route table (b) there is a default route → gateway mapping, so it might be possible to detect a control message that wants to reconfigure the default route.



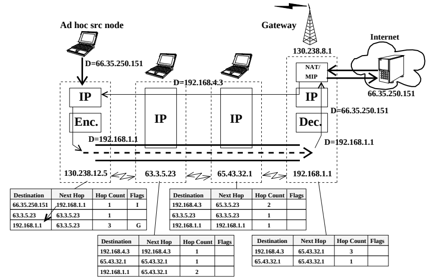
State Replication:

When a default route is repaired or updated, any new intermediate nodes must gather all the host route mapping state of upstream nodes. In the illustration below, node A is communicating with Internet hosts through gateway (GW). A's host route state S_A is not replicated when node B repairs the route to GW. Node D will not be able to forward packets to host(s) represented by state S_A.



Forwarding using Tunnels

Packets to Internet hosts are encapsulated and sent to the gateway where they are decapsulated. Reactive routing protocols can route these packets without modifications. From the gateway to the ad hoc source node, no tunnel is needed. Tunneling has a small overhead due to the encapsulation and risk of fragmentation. Also, decapsulation is required at the gateway. Tunneling to gateways was first proposed in MIPMANET (Mobihoc'00). We have a setup as shown below:

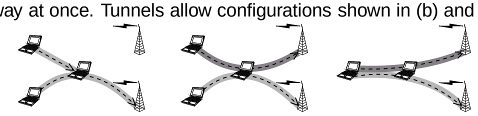


Benefits:

Protocol transparency. Tunneling is transparent with existing routing protocols. Extra logic and state is only needed at the source node and the gateway.

Route aggregation. Tunneling achieves route aggregation on intermediate nodes.

Multiple gateways. Tunnels work well with multiple gateways and allow multihoming and efficient hand-over. In the figure below, default routes (a) can only point to one gateway at once. Tunnels allow configurations shown in (b) and (c).

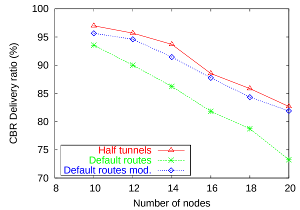


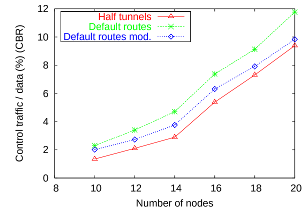
Stability. Encapsulation ensures that the source node controls the gateway relay point. Tunnels cannot be accidentally diverted on intermediate nodes as default routes can.

Efficient forwarding. Source nodes need to do two look-ups in their routing table and intermediate nodes only one look-up. In contrast, default routes require at least two on all nodes.

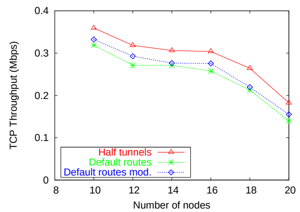
Evaluation and Conclusion

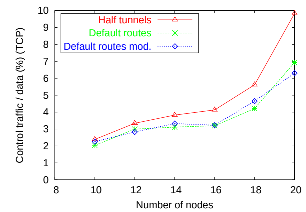
We evaluate the forwarding strategies in simulation. The network has fixed density, two gateways and 10 to 20 mobile nodes. Gateways are MIP agents and two ad hoc nodes communicate with an Internet host. Results are averaged over 50 randomly generated scenarios with random waypoint mobility. We have implemented both default routes and tunnels with the AODV protocol. A *proxy route reply* solution is used for gateway discovery. For reference we also have a modified default route version that forwards any incoming packets on a default route and that drops route replies that wants to reconfigure an existing default route. This will work because we only have traffic to Internet hosts.





Using CBR traffic we find that tunnels have the best performance. Default routes have problems and the improved results for the modified default routes indicate that the bad performance is caused mainly by the state replication problem, since there is no return traffic.





Looking at TCP performance, the modified default route forwarding is now closer to normal default routes. Gateway tracking is more important for TCP (i.e., two-way traffic), which is broken in both default route approaches. This can be seen from the reduced routing overhead (less control traffic when ACKs are lost and TCP timeouts). *With default routes, nodes may think that they are forwarding packets to a specific gateway, when they are in fact not.* Therefore, they will never re-register with the agent at the new gateway. Tunneling has a larger overhead because it is able to route more packets.

The conclusion is that tunneling packets to a gateway in ad hoc networks with flat addressing and reactive routing is more efficient and flexible compared to default routes. In fact, default routes operate incorrectly in some situations, particularly with multiple gateways.